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Using the Schmidt Hammer on Rock Mass Characteristic in Sedimentary Rock at Tutupan Coal Mine

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Abstract

The uniaxial compressive strength is one of important parameter to determine the shear strength of rock mass by the rock classification method. To determine uniaxial compressive strength used by a testing on laboratory or in practically can use the index method, in this research, alternatively is to use Schmidt Hammer. A method used Schmidt Hammer to determine the uniaxial compressive strength of rock is to calibrate between Schmidt Hammer Rebound (R) and uniaxial compressive strength test of laboratory and its the results are an empirical equation. The advantage of this method can practically to assess the strength of rocks in the field. At this paper is one of the alternative uses of the uniaxial compressive strength determining in sedimentary rocks in Warukin Formation at Tutupan open pit coal, South Kalimantan, Indonesia. And the next research is going to process towards another formation.

1. Introduction

The management of Open Pit Adaro coal mine is very concerned with keeping slopes stable because the pit is currently being mined at a very deep level, about 190 m below the original surface, some areas are very steep and it stretches 17 km from south to north east. The coal bearing strata is dominated by weak and friable to medium strong sandstone and mudstone of young formation (Warukin Formation) and in particular the mine experiences high rainfall. Having learned the local environmental condition, it is apparent that the most influence factor to the potential slope failure is the strength deterioration of the coal bearing strata. Currently, the coal mining in Tutupan mine PT. Adaro Indonesia has reached a depth of more than 190 m with elevations as low as -98 mRL and this will get deeper to a depth of -204 mRL in order to fulfill the world coal demand. One of method determine uniaxial compressive strength is index method the Schmidt Hammer (SH).

The SH originally designed for testing the hardness of concrete in 1948 was first used in a geomorphological context in the 1960s. The SH have become the advantages and disadvantages of the device for measuring rock characteristics and has been used for an increasing range of purposes, including the study of various weathering phenomena a range.

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2. Previous Studies

The instrument measures the distance of rebound of a controlled impact on a rock surface. There are now several version of the hammer. The 'N' type it can provide data on a range of the rock types from weak to very strong with compressive strengths that range from 20 to 250 MPa. The 'L' type hammer has an impact tress time lower than the'N' type and the 'P' type is a pendulum hammer for testing materials of very low hardness, with compressive strength of less than 70 kPa. When the SH is pressed against a surface, its piston is automatically released onto the plunger. Part of the piston's impact energy is consumed by absorption and is transformed into hear and sound. The remaining energy represents the impact penetration resistance of the surface. This enables the piston to rebound. The distance traveled by the piston after it rebounds is called the rebound value (R). Harder rocks have higher R values (Gaudie, 2006). Rebound values are influenced by gravitational forces to varying degrees so that non-horizontal rebound values must be normalized with reference to the horizontal direction (Day &Gaudie, 1977). The R Value is shown by a pointer on a scale on the side of the instrument (range 10 – 100). It us therefore important that the Schmidt Hammer is used with care and that it is properly calibrated (McCarroll, 1987).

A very substantial number of R value has been obtained from many different rock types in many parts of the world (Gaudie, 2006). At one end of the scale 'weak' rocks such as chalk, aeolianite and marls have low compressive strength. At the other end, silicates, very hard limestones, quarzites, and various igneous rocks many have values that exceed 60, and very occasionally 70.

Goudie (2006) made conclusion of used of the SH that the SH is a convenient means of establishing rock hardness in the field, providing that certain precautions are taken in the light of its known limitations. Portable, cheap, free from operator variance, simple and easy calibrated and free from any noticeable temperature effects, it can with due care produce rock hardness values that correlate well with such parameters as uniaxial compressive strength or Young's Modulus of Elasticity.

The SH tests are increasingly quantitative. The latter is recommended for obtaining estimates of wall strength for subsequent calculation of shear strength, when utilizing the wall roughness coefficient (JRC) described under roughness.

Selby (1993) has divided rocks up into 6 classes (Table 1). This provides a useful basis for classifying rocks and forgiving a clear indication of a rock's character.

Because of its speed, simplicity, portability, low cost and non-destructiveness, the SH has been used as a means of estimating other rock properties, such as compressive strength (Sendir, 2002). Various researchers have studied the relationship between rock compressive strength and SH R values as shown Table 2. The R^2 value has range between 0.7 and 0.99 (Yasar&Erdogan, 2004). The regressions vary greatly between different rock type, however (Dincer et al., 2004) and so should be used only for particular lithologies (Sachpazis, 1990). Nonetheless, as Hack and Huisman (2002) point out, a large number of simple test in the filed, using the SH, will tend to give a better estimate of the intact rock strength at various location than a limited number of more complex test.

3. Proposed Equation

As mentioned before that the equation of SH (Goudie, 2006) include the UCS of varied rock that is obtained from non-tropical countries. The samples are obtained from coal bearing strata that is located in the tropical country so that rock strength deterioration due to weathering is taken into account. The weathering process is simulated through slake durability tests. It is expected that the proposed equation will be more representative than the previous one in the application for estimate for uniaxial compressive strength in Indonesian open pit coal mine.

Rock mass characterization studies produce empirical equation relationship between the uniaxial compressive strength and the SH Rebound (R) shown the power function (Figure 1).

The previous researchers gave the R value for mudstone and sandstone that varies is between 10 and 38.6 for the mudstone and 10 to 44.7 for sandstone (Table 3). While the value of R for the mudstone and sandstone of the cover turned out to be among the respective 10 – 26 and 10 – 28.

The previous researchers provide empirical equation of the relationship uniaxial compressive strength and Schmidt Hammer Rebound with varied functions, logarithmic functions, exponential, power, and linear (Table 4). The purposed empirical equation for estimate UCS to weak rock on the coal bearing strata in Warukin Formation, is:

$$UCS = 0.308R^{1.327} \quad (1)$$

where: UCS= uniaxial compressive strength (MPa), R = Schmidt hammerrebound

Table 1. Approximate strength classification of rocks (Selby, 1993)

Description	Uniaxial compressive strength, MPa	Point load strength $I_{s(50)}$, MPa	Schmidt Hammer N-Type, 'R'	Characteristic rocks
Very weak rock – Crumbles under shrap blows with geological pick point, can be cut with pocket knife.	1-25	0.04-1.0	10-35	Weathered weakly Compacted sedimentary rocks-chalk, rock salt
Weak rock – shallow Cuts or scraping with pocket knife with difficulty, pick point indents deeply with firm blow	25-50	1.0-1.5	35-40	Weakly cemented Sedimentary rocks – coal siltstone, also schist
Moderately strong rock – knife cannot be used to scrape or peel surface, shallow indentation under firm blow from pick point	50-100	1.5-4.0	40-50	Competent sedimentary Rocks – sandstone shale, slate
Strong rock – hand-held sample breaks with one m firm blow from hammer end of geological pick	100-200	4.0-10.0	50-60	Competent igneous and Metamorphic rocks – marble, granite, gneiss
Very strong rock – requires many blows a from geological pick to break intact sample	>200	>10	>60	Dense fine-grained igneous snd metamorphic rocks – quartzite, dolerite, gabbro, basalt.

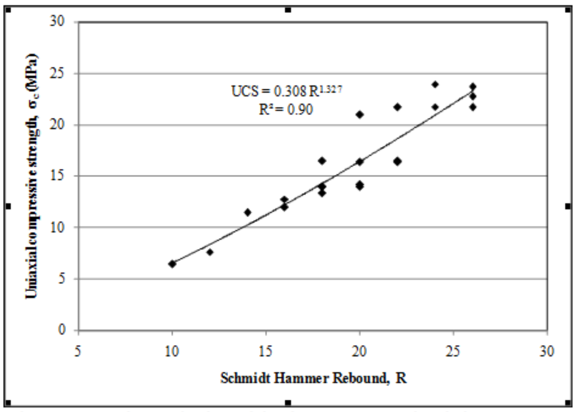

Figure 1. The relationship between uniaxial compres- sive strength and the Schmidt Hammer Rebound (R)

Table 2.Correlation between Schmidt hammer rebound and uniaxial compressive strength and Young's modulus (Gaudie, 2006)

Equation	R^2	Reseacher	Lithology
UCS			
UCS = 6.9 x $10^{(0.0087\gamma R + 0.16)}$	0.94	Deere and Miller (1966)	varied
UCS = 6.9 x $10^{(1.348\gamma R - 1.325)}$	-	Aufmuth (1973)	varied
UCS = 0.447exp(0.045(R + 3.5) + γ)	-	Kidybinski (1980)	Coal, Shale, mudstone
UCS = 2R	0.72	Singh et al. (1983)	Sandstone, siltstone
UCS = 0.4RLM – 3.6	0.94	Sheorey et al. (1984)	Coal
UCS = 0.994R – 0.383	0.70	Haramy and De Marco (1985)	Coal
UCS = 702R - 1104	0.77	O'Rourke (1989)	Sandstone
UCS = 2.208$e^{0.067R}$	0.96	Katz et al. (2000)	Limestone, sandstone
UCS = exp(0.818 + 0.059R)	0.98	Yilmaz and Sendir (2002)	Gypsum
UCS = 2.75R – 36.83	-	Dincer et al (2004)	Andesite, basalts, tuffs
UCS = 2.22R – 47.67	-	Aggistalls et al (1996)	Gabbros, basalts
E			
E = 6.95γ^2R – 1.14 x 106	0.88	Deere and Miller (1966)	Varied
E = 6.9 x $10^{(1.06 \log(\gamma R) + 1.86)}$	-	Aufmuth (1973)	varied
E = 0.00013$R^{3.09074}$	0.99	Katz et al. (2000)	Syenite, granite
E = exp(1.146 + 0.054R)	0.91	Yimaz and Sendir (2002)	gypsum

UCS = Uniaxial compressive strength (MPa), E = Young's modulus (MPa), R = Schmidt hammer rebound number, γ = rock density (gr/cm^3) (Yasar&Erdogan (2004)

Table 3. Schmidt Hammer rebound (R) of sandstone and mudstone

No	Lithology	Country	Schmidt hammer 'R'	researchers
1	Mudstone	Jepang	10.5 – 32	Hayakawa &Matsukara (2003)
2	Mudstone	Ankara, Turkey	27.1 – 38.6	Gokceogal&Aksoy (2000)
3	Mudstone	Kaikoura, New Zealand	32 – 35	Stephenson & Kirk (2000)
4	Mudstone	Tutupan, Indonesia	10 – 26	Saptono&Kramadibrata
5	Sandstone	Ankara, Turkey	18.3 – 33.6	Gokceogal&Aksoy (2000)
7	Sandstone	South East, Jordan	41 – 44.7	Goudie, et al (2002)
8	Sandstone	Tutupan, Indonesia	10 – 28	Saptono&Kramadibrata

Table 4. Proposed equation correlation between Schmidt hammer rebound and uniaxial compressive strength

Equation	R^2	Researcher	Lithology
UCS = 6.9 x $10^{[0.0087\gamma R + 0.16]}$	0.94	Deere & Miller (1966)	varied
UCS = 6.9 x $10^{[1.348 \log(\gamma R) – 1.325]}$	-	Aufmuth (1973)	varied
UCS = 0.447$\exp^{[0.045(R + 3.5) + \gamma]}$	-	Kidybinski (1980)	coal, shale, mudstone
UCS =0.308 $R^{1.327}$	0.90	Saptono&Kramadibrata	sandstone, mudstone
UCS = 2R	0.72	Singh et al (1983)	sandstone, mudstone
UCS = 2.75R – 36.83	-	Dincer et al (2004)	Andesite, basalt, tuff
UCS = 702R - 1104	0.77	O'Rourke (1989)	sandstone

4. Concluding Remarks

Determination of measurement the weak rock strength in the field we need a method that is fast, easy and precise so one of method is to use the index measuring device, which use Schmidt Hammer Rebound. Its result is a function empirical equation of relationship between uniaxial compressive strength and Schmidt hammer rebound (R). This research would be to replace qualitative geological hammer in sedimentary rock in coal bearing strata in Warukin Formation. This research is going to process towards another formation in tropical country as Indonesia.

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References

1. Aggistalis, G., Alivizatos, S., Stamoulis, D. and Stournaras, G., Correlating uniaxial compressive strength with Schmidt hardness, point load index, Young's Modulus, and mineralogy of gabbros and basalts (northern Greece). Bulletin of the International Association of Engineering Geology 54 3–11, (1996).
2. Aufmuth, R.E., A systematic determination of engineering criteria for rocks. Bulletin of the Association of Engineering Geology 11, 235–45, (1973).
3. Day, M.J., Rock hardness: field assessment and geo- morphic importance. Professional Geographer 32, 72–81, (1980).
4. Deere, D.U. and Miller, R.P., Engineering classification and index properties for intact rocks. Technical Report, Air Force Weapons Laboratory, New Mexico, AFNL-TR, 65–116, (1966).
5. Dinçer, I., Acar, A., Cobangulu, I. and Uras, Y., Correlation between Schmidt hardness, uniaxial compressive strength and Young's modulus for andesites, basalts and tuffs. Bulletin of Engineering Geology and the Environment 63, 141–48, (2004).
6. Gökçeoglu, C. and Aksoy, H., New approaches to the characterization of clay-bearing, densely jointed and weak rock masses. Engineering Geology 58, 1–23, (2000).
7. Goudie, A.S., The Schmidt Hammer in Geomor- phological Research, Progress in Physical Geography 30. 6. pp. 703-718, (2006).
8. Goudie, A.S., Migon, P ., Allison, R.J. and Rosser, N., Sandstone geomorphology of the Al-Quwayra area of south Jordan. Zeitschrift für Geomorphologie 46, 365–90, (2002).
9. Haramy, K.Y. and De Marco, M.J., Use of Schmidt Hammer for rock and coal testing. 26th US Symposium on Rock Mechanics, 26–28 June, Rapid City, 549–55, (1985).
10. Hayakawa, Y. and Matsukura, Y., Recession rates of waterfalls in Boso Peninsula, Japan, and a predictive equation. Earth Surface Processes and Landforms 28, 675–84, (2003).
11. Hack, R. and Huisman, M., Estimating the intact rock strength of a rock mass by simple means. Proceedings 9th Congress of the International Association for Engineering Geology and the Environment, Durban, South Africa, 16–20 September 2002, 1971–77, (2002).
12. Katz, O., Reches, Z. Roegiers, J.-C., Evaluation of mechanical rock properties using a Schmidt Hammer. International Journal of Rock Mechanics and Mining Sciences 37, 723–28, (2000).
13. Kidybinski, A., Bursting liability indices of coal. International Journal of Rock Mechanics and Mining Sciences Geomechanical Abstracts 17, 167–71, (1980).
14. McCarroll, D., The Schmidt Hammer in geomor- phology: five sources of instrument error. BGRG Technical Bulletin 36, 16–27, (1987).
15. O'Rourke, J.E., Rock index properties for geo- engineering, underground development. Mining Engineering 106–10, (1989).
16. Sachpazis, C.I., Correlating Schmidt hardness with compressive strength and Young's modulus of carbonate rocks, Bulletin of the International Association of Engineering Geology 42, 75–83, (1990).
17. Saptono, S., Pengembangan Metode Analisis Stabilitas Lereng Berdasarkan Karakterisasi Batuan di Tambang Terbuka Batubara. Disertasi Doktor, Rekayasa Pertambangan, Institut Teknologi Bandung, (2012).

18. Selby, M.J., A rock mass strength classification for geomorphic purposes: with test from Antarctica and New Zealand. Zeitschrift für Geomorphologie 24, 31–51, (1980).
19. Sheorey, P .R., Barat, D., Das, M.N., Mukherjee, K.P . and Singh, B., Schmidt hammer rebound data for estimation of large scale in situ coal strength. International Journal of Rock Mechanics and Mining Sciences 21, 39–42, (1984).
20. Singh, R.N., Hassani, F .P . and Elkington, P .A.S., The application of strength and deformation index testing to the stability assessment of coal measures excavations. Proceedings 24th US Symposium on Rock Mechanics, Texas A&M University, 599–609, (1983).
21. Stephenson, W.J. and Kirk, R.M., Development of shore platforms on Kaikoura Peninsula, South Island, New Zealand II: the role of subaerial weathering. Geomorphology 32, 43–56, (2000).
22. Yasar, E. and Erdogan, Y., Estimation of rock physicomechanical properties using hardness methods. Engineering Geology 71, 281–88, (2004).
23. Yilmaz, I. and Sendir, H., Correlation of Schmidt hardness with unconfined compressive strength and Young's modulus in gypsum from Sivas (Turkey). Engineering Geology 66, 211–19, (2002).